TECHNICAL MEMORANDUM NO 5

TOXICITY ASSESSMENT

HUMAN HEALTH RISK ASSESSMENT
WALNUT CREEK PRIORITY DRAINAGE
OPERABLE UNIT NO 6

DRAFT FINAL

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

U S DEPARTMENT OF ENERGY
Rocky Flats
Golden Colorado

ENVIRONMENTAL MANAGEMENT DEPARTMENT

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1.0
INTRODUCTION

The purpose of this Toxicity Assessment Technical Memorandum is to present the toxicity factors that will be used in the human health risk assessment for Operable Unit No 6 (OU6) at the Rocky Flats Plant This Technical Memorandum presents EPA-verified and provisional carcinogenic slope factors (SFs) and noncarcinogenic reference doses or reference air concentrations (RfDs or RfCs) for potential chemicals of concern detected in environmental media in OU6 In the human health risk assessment, estimated levels of intake of chemicals of concern are compared with the toxicity factors to estimate potential risk associated with exposure

Toxicity factors are provided for all potential chemicals of concern; i e, metals and radionuclides detected above background levels and all detected organic target analytes Chemicals of concern for evaluation in the quantitative baseline risk assessment were selected using established procedures from EPA guidance (USEPA 1989) and agreed upon by all parties to the Interagency Agreement for Rocky Flats signed in 1991 The details and the results of the chemicals of concern selection process are presented in Technical Memorandum No 4, Chemicals of Concern (USDOE 1994)

The principal indexes of toxicity for chemicals with noncarcinogenic effects are the oral RfD and inhalation RfC RfDs and RfCs can be considered threshold doses or exposure levels At chemical doses or exposures below threshold values adverse effects are not expected to occur RfDs and RfCs incorporate a number of safety factors to ensure that they are protective of the health of all human populations, including sensitive subgroups (e g, children and the elderly)

Oral and inhalation SFs are used to characterize the potency of carcinogens SFs are used to estimate the upper-bound probability of an individual developing cancer as a result of exposure to a potential carcinogen A SF is a dose-response factor used to relate carcinogenic response to chemical dose EPA policy assumes that carcinogenic responses have no threshold, and that exposure to a carcinogen may result in some finite cancer risk at any dose, no matter how small (USEPA 1989)

Slope factors for radionuclides are derived considering the energy level of the radionuclide and residence time of the radionuclide in various body tissues Duration of exposure is determined by the residence time of the radionuclide Adverse health effects of external exposure to radionuclides are determined by the energy level of the radionuclide and duration of the exposure (i e , time spent at the exposure point)

EPA assumes that any dose of a radionuclide has the potential to produce carcinogenic effects (no threshold) EPA does not recommend the evaluation of noncarcinogenic effects of radionuclides because the impacts have been shown to be insignificant compared to carcinogenic effects at most EPA Superfund sites with radionuclide contamination (USEPA 1989) EPA has developed both internal (i e , inhalation and ingestion) and external SFs for the carcinogenic response to radionuclide exposure (USEPA 1993a and 1994) Although more recent data on radionuclide dose-response relationships than that used to develop the EPA SFs are available (i e , the NRC 1990 BEIR V report and ICRP Publication No 60), they have not yet been approved by EPA Therefore, the currently approved EPA SFs (USEPA 1993a) will be used in the toxicity assessment section of the human health risk assessment for OU6

__Note on assessing effects of dermal exposure__ Oral toxicity factors are generally used to evaluate toxic effects from dermal contact with contaminated media This approach is acknowledged by EPA (USEPA 1989, 1992) Oral toxicity factors relate the toxic response to an administered (i e , ingested) dose of chemicals, only some of which may be absorbed by the body, whereas dermal absorption results in an absorbed dose of chemicals Therefore, USEPA (1989) suggests adjusting the oral toxicity factors by chemical-specific gastrointestinal absorption rates, if available, to yield toxicity factors for dermally absorbed chemicals Regarding using oral toxicity factors to evaluate response to dermal exposure, USEPA (1992) states

> Until more appropriate dose-response factors are available, it is recommended that assessors use the oral factors Alternatively, if estimates of the gastrointestinal absorption fraction are available for the compound of interest in the appropriate vehicle, then the oral dose-response factor, unadjusted for absorption, can be converted to an absorbed dose basis Lacking this

information, the oral factor should be used as is accompanied by a strong statement of the uncertainty involved (p 10-9, 10-10)

Since chemical-specific gastrointestinal absorption rates are not available for most chemicals, unadjusted oral toxicity factors will be used initially to assess effects of dermal absorption If dermal absorption of particular chemicals is demonstrated to be a potential significant contributor to overall risk in the risk assessment, a more detailed analysis of the toxicity by dermal absorption may be warranted

USEPA guidance (USEPA 1989) states that it is inappropriate to use oral SFs to evaluate the risks associated with dermal exposure to polycyclic aromatic hydrocarbons (PAHs), which can cause skin cancer through direct action at the point of application In accordance with EPA guidance, generally only a qualitative assessment of risks from dermal exposure to PAHs is possible Therefore, only oral exposures to PAHs will be evaluated quantitatively in the risk assessment

The RfDs, RfCs, and SFs that will be used in the OU6 risk assessment were obtained from the following sources

- EPA's Integrated Risk Information System on-line database (USEPA 1994)
- EPA's Health Effects Assessment Summary Tables (USEPA 1993a)
- EPA's Environmental Criteria and Assessment Office (ECAO) for interim and provisional values

Section 2 0 of this Technical Memorandum discusses the basis of toxicity factors for chemicals and radionuclides and presents the chemical-specific toxicity factors that will be used in the risk assessment Section 3 0 lists the references cited

The following sections discuss the derivation of RfDs, RfCs, and SFs Table 2-1 presents the RfDs and RfCs for noncarcinogenic effects as well as SFs and the cancer weight of evidence for carcinogenic effects for potential chemicals of concern at OU6 Toxicity factors for inhalation and ingestion exposure are included in the table if available Table 2-1 also includes the inhalation RfDs calculated from RfCs using the equation described in section 2 1

Table 2-2 contains cancer slope factors for inhalation, ingestion, and external exposures to radionuclides EPA considers the critical effect of radionuclides to be carcinogenesis and the weigh-of-evidence to be Class A (human carcinogen)

2.1 TOXICITY FACTORS FOR NONCARCINOGENIC EFFECTS OF CHEMICALS

Substances that produce noncarcinogenic effects are generally thought to have a threshold dose below which there are no observable adverse health effects In developing a toxicity value for noncarcinogenic effects, the approach used by EPA is to identify this threshold dose, or no-observed-adverse-effect level (NOAEL), through studies with laboratory animals or from epidemiological (human) studies A NOAEL is defined as an experimentally (or epidemiologically) determined highest dose at which there was no observed statistically or biologically significant effect of concern For certain substances, only a lowest-observed-adverse-effect level (LOAEL) has been determined This is the lowest dose of a substance that produces either a statistically or biologically significant indication of the critical toxic effect The NOAEL or the LOAEL may be used in conjunction with appropriate uncertainty factors to calculate the RfD (or RfC) of a particular chemical (USEPA 1989) Uncertainty factors (usually a factor of 10 each) are used to account for protection of sensitive individuals, extrapolation from animals to humans, extrapolation from subchronic studies to chronic exposure, and extrapolation from LOAELs to NOAELs In addition, modifying factors ranging from >0 to 10 may be included to reflect a qualitative assessment of additional uncertainties in the derivation of the RfD or RfC

The majority of our toxicological knowledge of chemicals comes from experiments on laboratory animals Experimental animal data historically have been relied upon by regulatory agencies and other expert groups to assess the hazards of human chemical exposures, although uncertainty is inherent in this approach because there are known interspecies differences in chemical absorption, metabolism, excretion, and toxic responses There are also uncertainties concerning the relevance of animal studies using exposure routes (i e , intravenous injection) that differ from the human exposure routes under consideration Additionally, the extrapolation of results from short-term or subchronic animal studies to long-term exposures in human has inherent uncertainty (USEPA 1989)

Despite the limitations of experimental animal data, such information is essential for chemical toxicity assessment, especially in the absence of human epidemiological evidence The uncertainty factors used in the derivation of RfDs and RfCs are intended to compensate for data limitations The use of uncertainty factors is conservative by design and is meant to result in protective toxicity values (USEPA 1989) The EPA bases the RfD on the most sensitive animal species tested (i e , the species that experiences adverse effects at the lowest dose) RfDs are typically calculated by dividing the NOAEL (or LOAEL) by uncertainty factors, which range from 10 to 1000 EPA has developed a standard set of uncertainty factors to account for variations in the sensitivity of individuals within a population and the extrapolation of data from experimental animals to humans The RfD is expressed in units of intake of milligrams of chemical per kilogram of body weight per day (mg/kg-day) for oral exposure The methodology for deriving RfDs is more fully described in the EPA's current human health risk assessment guidance (USEPA 1989)

Potential hazards from inhalation exposures may be estimated by comparing an air concentration of a chemical to the RfC RfCs are expressed in concentration units of milligrams of chemical per cubic meter of air (mg/m^3) For the purposes of the OU6 risk assessment, in order to assess cumulative effects of both oral and inhalation exposures, the RfCs are converted to inhalation RfDs so that chemical intake, rather than inhalation exposure, can be evaluated A body weight of 70 kg and a respiration rate of 20 m^3/day are used to convert the RfC to the RfD (mg/kg-day) using the following equation

The EPA defines a chronic RfD (or RfC) as an estimate of a daily exposure level for the human population that is unlikely to result in deleterious effects during a lifetime (70 years,

$$RfD\ (mg/kg\text{-}day) = RfC \left(\frac{\frac{mg}{m^3}\ x\ 20\ m^3}{70\ kg\text{-}day} \right)$$

according to EPA guidance) A chronic RfD is used to evaluate the potential noncarcinogenic hazards associated with long-term chemical exposures (7 years to a lifetime) Subchronic RfDs have been developed for some chemicals to characterize potential noncarcinogenic hazards associated with short-term chemical exposures The EPA defines subchronic exposure as periods ranging from 2 weeks to 7 years (USEPA 1989) Subchronic RfDs tend to be higher for many chemicals, generally by a factor of ten, than chronic RfDs because higher doses can be tolerated for a shorter exposure duration Only chronic RfDs and RfCs are shown in Table 2-1

2.2 SLOPE FACTORS FOR CARCINOGENIC EFFECTS OF CHEMICALS

In estimating the risk posed by potential carcinogens, it is EPA practice to assume that any exposure level is associated with a finite probability, however minute, of producing a carcinogenic response This is a conservative (protective) assumption that may overestimate the response to low doses of some suspected carcinogens, especially those for which there is scientific evidence of a threshold dose In other words, EPA assumes that a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation This mechanism for carcinogenicity is referred to as "non-threshold" since there is theoretically no level of exposure that does not pose a small probability of producing a carcinogenic response

The EPA also uses an evaluation process in which the chemical is assigned a cancer weight-of-evidence classification The weight-of-evidence classification describes the degree of confidence or likelihood, based on scientific evidence, that the substance is a human carcinogen Table 2-3 defines the current EPA weight-of-evidence classification system

SFs for most chemicals are usually based upon the results of animal studies which, as previously discussed, involve uncertainty There is uncertainty whether all animal carcinogens are also carcinogenic in humans While many chemical substances are carcinogenic in one or more animal species, only a small number of chemical substances are known to be human carcinogens The EPA assumes that humans are as sensitive to all animal carcinogens as the most sensitive animal species This policy decision is designed to prevent underestimating risk and introduces the potential to overestimate carcinogenic risk (USEPA 1989)

SFs are calculated from experimental or epidemiological data that quantitatively define the relationship between average lifetime dose and carcinogenic risk (USEPA 1989) A number of mathematical models and procedures have been developed to extrapolate from carcinogenic responses observed at high doses in laboratory animals to potential responses expected at low doses in humans EPA uses a conservative mathematical model, the linearized multistage model, for low-dose extrapolation EPA identifies the SF as the upper 95th percentile confidence limit of the slope of the resulting dose-response curve The SF is expressed in units of risk per mg/kg-day or $(mg/kg\text{-}day)^{-1}$ and is used to estimate excess incremented lifetime cancer-risk from the lifetime average daily intake of a chemical This represents an estimation of an upper-bound probability that an individual will develop cancer as a result of exposure to the potential carcinogen This model provides a conservative (protective) estimate of cancer risk at low doses and is likely to overestimate the actual cancer risk The EPA acknowledges that actual SFs are likely to be between zero and the estimate provided by the linearized multistage model (USEPA 1989)

2 3 SLOPE FACTORS FOR RADIONUCLIDES

EPA's Health Effects Assessment Summary Tables (USEPA 1993a) list cancer SFs for selected radionuclides of potential concern at Superfund sites These values were calculated by the Office of Radiation Programs and are intended for use in human health risk assessments EPA classifies all radionuclides as Group A carcinogens based on the extensive weight-of-evidence provided by epidemiological studies of radiation-induced cancers in humans According to EPA, potential health risks at most CERCLA radiation sites are usually based on the radiotoxicity (radioactivity), rather than chemical toxicity

Radionuclides that enter the body may become incorporated into body tissues and emit alpha, beta, or gamma radiation for the duration of the radionuclide's lifetime The potential adverse effects of radiation are proportional to energy deposition The energy deposited in tissues is proportional to the decay rate and the type of radiation (alpha, beta, gamma) rather than the mass of the radionuclide (USEPA 1989) Radionuclide intake is typically expressed in terms of activity, either Curies (Ci) or Becquerels (Bqs) rather than mass (mg) Activity refers to the number of nuclear disintegrations per unit time The historic unit of activity is the Ci, which is equal to 3 7 x 10^{10} disintegrations per second The SI (Systeme Internationale) unit of activity is the Bq, equal to one disintegration per second (1 Bq = 2 7 x 10^{11} Ci) EPA SFs are provided in both units, risk per picocurie (pCi or 1 x 10^{12} Ci^{u})^{1} and risk per Bq (Bq)^{1} This Technical Memorandum uses radionuclide SFs expressed in risk per pCi (Table 2-2)

EPA SFs for radionuclides are characterized as best estimates (median or 50th percentile) of the age-averaged, lifetime excess total cancer incidence (fatal and nonfatal) risk per unit exposure to a radionuclide The SFs are based on the unique chemical, metabolic, and radiological properties of individual radionuclides They were calculated using a non-threshold, linear dose-response model The model accounts for the amount of radionuclide absorbed into the body, distribution, and retention, as well as the age, sex, and weight of an average individual Therefore, EPA SFs for radionuclides are not expressed as a function of body weight or time, and do not require corrections for absorption or lung transfer efficiencies These slope factors include daughter products when appropriate (USEPA 1993a)

Ingestion and inhalation SFs estimate risk per unit of activity inhaled or ingested expressed as risk/pCi External exposure SFs are best estimates of risk for each year of exposure to external radiation from photon-emitting radionuclides distributed uniformly in a thick layer of soil They are expressed as risk/yr per pCi/gram soil It should be noted that the dose delivered to tissues from external radiation occurs only while the radiation field is present However, the dose delivered to body tissues due to intake of radionuclides consumed in soil, water, and/or food continues long after intake of the radionuclide has ceased

Radionuclide concentrations in air, water, or soil are multiplied by intake rates for internal exposure, or by exposure times for external exposure, and then multiplied by SFs to estimate potential health risk Radionuclide intake can also be multiplied by a dose coefficient to estimate equivalent dose, which can then be compared to a radiation protection standard Differences in the biological effects of different types of ionizing radiation (i e , alpha, beta, gamma) are accounted for in the dose coefficients Table 2-4 contains the dose coefficients for plutonium-239, plutonium-240, americium-241, and uranium isotopes They are the chief radionuclide chemicals of concern for OU6 identified in the Chemicals of Concern Technical Memorandum (USDOE 1994)

Equivalent dose can be calculated for the whole body when there is uniform irradiation of all tissues, or for individual organs when selected tissues are irradiated non-uniformly Rem (radiation equivalent man) is the conventional unit of dose equivalent The corresponding SI unit, the Sievert, is equal to 100 rem Absorbed dose is the energy deposited by ionizing radiation per unit mass of absorbing material (i e , tissue) Ionizing radiation can only have adverse effects on biological tissues when the radiation is absorbed in tissue The conventional unit is the rad which is equal to 100 erg per gram The SI unit, gray, is equal to 100 rad

3.0
REFERENCES

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U S Environmental Protection Agency (USEPA) 1989 Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A) EPA/540/1-89/002 December, 1989

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U S Environmental Protection Agency (USEPA) 1993a Health Effects Assessment Summary Tables (HEAST) Annual Update, FY1993 (including Supplement No 1) OHEA ECAO-CIN-909

U S Environmental Protection Agency (USEPA) 1993b Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons Final Draft ECAO-CIN-842 March

U S Environmental Protection Agency (USEPA) 1993c External Exposure to Radionuclides in Air, Water and Soil Report No 12 EPA/402-R-93-081 September

U S Environmental Protection Agency (USEPA) 1994 Integrated Risk Information System (IRIS), On-line database

TABLE 2-1
ROCKY FLATS OU6
TOXICITY FACTORS FOR
ORGANIC COMPOUNDS AND METALS

	Slope Factors 1/(mg/kg-day)		EPA Cancer	Reference Doses mg/kg-day		Reference
Analyte	Oral	Inhalation	Weight of Evidence	Oral	Inhalation (*)	Concentration mg/m³
1 1 Dichloroethane	-	-	C	1 0E-01 (2)	1 40E-01	5 0E-01 (3)
1,1-Dichloroethene	6 0E-01 (1)	1 2E-01 (2)	C	9 0E-03 (1)	-	
1,2,4-Trichlorobenzene	-		-	1 0E-02 (1)	3 00E-03	9 0E-03 (3)
1 2 Dichloroethane	9 1E-02 (1)	9 1E-02 (1)	B2	-		
1,2 Dichloroethene			-	9.0E-03 (2)		
cis-1,2-Dichloroethene		-		1.0E-02 (2)		
1,4-Dichlorobenzene	2 4E-02 (2)	-	C	-	2 30E-01	8 0E-01 (2)
2 Butanone	-	-	D	6 0E-01 (1)	3 00E-01	1 0E+00 (1)
2-Chlorophenol			-	5 0E-03 (1)	-	-
4-Methyl 2-pentanone	-	-	-	5 0E-02 (2)	2 30E-02	8 0E-02 (3)
4-Methylphenol			-	5 0E-03 (6)		
Acenaphthene	-			6 0E-02 (1)		
Acetone		-	-	1 0E-01 (1)	-	-
Aldrin	1 7E+01 (1)	17 1E+00 (1)	B2	3 0E-05 (1)	-	-
Aluminum			-	2.9E+00 (6)		
Anthracene	-	-		3.0E-01 (1)		
Antimony		-	-	4 0E-04 (1)	-	-
Arsenic	1 7E+00 (7)	1 5E+01 (7)	A	3 0E-04 (1)		
Barium	-	-	-	7 0E-02 (1)	1 40E-04	5 0E-04 (3)
Benzene	2 9E-02 (1)	2 9E-02 (1)	A	-	-	-
Benzo(a)anthracene	7 3E-01 (4)	-	B2	-		
Benzo(a)pyrene	7 3E+00 (4)		B2	-		
Benzo(b)fluoranthene	7 3E-01 (4)	-	B2			-
Benzo(k)fluoranthene	7.3E-02 (4)	-	B2	-		
Benzoic acid	-	-	-	4 0E+00 (1)		-
Benzyl alcohol		-	-	3 0E-01 (2)		
Beryllium	4 3E+00 (1)	8 4E+00 (1)	B2	5 0E-03 (1)	-	-
Bis(2-ethylhexyl)phthalate	1 4E-02 (1)	-	B2	2 0E-02 (1)		
Butylbenzene (sec, tert)			-	1 0E-02 (6)	-	-
Butyl benzylphthalate	-	-	C	2 0E-01 (1)		
Cadmium (food)		6 3E+00 (1)	B1	1 0E-03 (1)		
Cadmium (water)	-	-	B1	5 0E-04 (1)		
Carbon disulfide		-		1 0E-01 (1)	2 90E-03	1 0E-02 (2)
Carbon tetrachloride	1 3E-01(1)	5 2E-02 (1)	B2	7 0E-04 (1)	-	
Chlorobenzene	-	-	-	2 0E-02 (1)	5 70E-03	2 0E-02 (3)
Chloroform	6 1E-03 (1)	8 0E-02 (1)	B2	1 0E-02 (1)	-	-
Chromium III		-	-	1 0E+00 (1)	-	-
Chrysene	7 3E-02 (4)		B2			
Cobalt	-	-	-	6 0E-02 (6)	-	-
Di n-butylphthalate		-	D	1 0E-01 (1)	-	-
Di-n-octylphthalate			D	2 0E-02 (2)		
Dibenzo(a,h)anthracene	7 3E+00 (4)		B2	-	-	-
Diethyl phthalate			-	8 0E-01 (1)		
Ethylbenzene			D	1 0E-01 (1)	3 00E-01	1 0E+01 (1)

TABLE 2-1
(Concluded)

Analyte	Slope Factors Oral	Slope Factors Inhalation	EPA Cancer Weight of Evidence	Reference Doses Oral	Reference Doses Inhalation (*)	RfC
Fluoranthene	-	-		4 0E-02 (1)	-	-
Fluorene	-			4 0E-02 (1)		
gamma-BHC	-	-	-	3 0E-04 (1)	-	-
Heptachlor epoxide	9 1E+00 (1)	9 1E+00 (1)	B2	1 3E-05 (1)	-	
Indeno(1 2,3-cd)pyrene	7 3E-01 (4)		B2	-	-	
Lithium	-	-	-	2 0E-02 (6)	-	-
Manganese (food)		-	D	1 4E-01 (1)	1 40E-05	5 0E-05 (1)
Manganese (water)	-	-	D	5 0E-03 (1)	-	-
Mercury	-	-	D	3 0E-04 (2)	9 00E-05	3 0E-04 (2)
Methylene chloride	7 5E-03 (1)	1 6E-03 (1)	B2	6 0E-02 (1)	9 00E-01	3 0E+00 (2)
Molybdenum		-		5 0E-03 (1)	-	
Naphthalene	-	-	-	4 0E-02 (6)	-	
Nickel (salts)	-		-	2 0E-02 (1)		
Nitrate	-	-		1 6E+00 (1)	-	
Pentachlorophenol	1 2E-01(1)	-	B2	3 0E-02 (1)	-	
Phenol		-	D	6 0E-01 (1)	-	
Polychlorinated biphenyls	7 7E+00 (1)		B2		-	
Pyrene			D	3 0E-02 (1)		-
Selenium	-	-		5 0E-03 (1)	-	-
Silver		-	D	5 0E-03 (1)	-	
Strontium	-		-	6 0E-01 (1)	-	
Styrene	-		-	2 0E-01 (1)	2 80E-01	1 0E+00 (1)
Tetrachloroethene	5 2E-02 (5)	2 0E-03 (5)	B2	1 0E-02 (1)	-	
Thallium (oxide)	-	-		7 0E-05 (2)	-	
Tin	-	-	-	6 0E-01 (2)	-	
Toluene			D	2 0E-01 (1)	1 10E-01	4 0E-01 (1)
Trichloroethene	1 1E-02 (5)	6 0E-03 (5)	B2			-
Xylenes		-	-	2 0E+00 (1)		
Vanadium		-		7 0E-03 (2)	-	
Zinc	-	-	D	3 0E-01 (1)	-	

Sources
(1) = IRIS
(2) = HEAST 1994
(3) = HEAST 1994 Table 2
(4) = (EPA 1993b)
(5) = Joan S Dollarhide, Superfund Health Risk Technical Support Center "Carcinogenicity Characterization of Perchloroethylene (PERC) and Trichloroethylene (TCE) (Luke Air Force Base Arizona) ECAO
(6) = Provisional values for aluminum, butylbenzene, cobalt, lithium, and naphthalene. USEPA ECAO
(7) = Converted from IRIS unit risks Oral proposed U R = 5 00E-05/ug/L Inhalation U R = 4 30E-03/ug/m3
Oral SF = 5 00E-05 x 1000ug/mg x 70kg/2L Inhalation SF = 4 30E-03/ug/m3x1000ug/mgx70kg/20m3
* Calculated from RfC RfD = RfC x 20m3/day/70kg.

TABLE 2-2
ROCKY FLATS PLANT OU-6
SLOPE FACTORS
FOR RADIONUCLIDES

Analyte	GI Absorption Factor (F_1)[1]	Oral (Risk/pCi)	ICRP Lung Class [2]	Inhalation (Risk/pCi)	External (Risk/yr/pCi/g)	EPA Cancer Weight of Evidence
Americium-241	1E-03	2 4E-10	W	3 2E-08	4 9E-09	A
Cesium-137 +D	1E+00	2 8E-11	D	1 9E-11	2 0E-06	A
Plutonium-239	1E-03	2 3E-10	Y	3 8E-08	1 7E-11	A
Plutonium-240	1E-03	2 3E-10	Y	3 8E-08	2 7E-11	A
Radium-226 +D	2E-01	1 2E-10	W	3 0E-09	6 0E-06	A
Radium-228 +D	2E-01	1 0E-10	W	6 6E-10	2 9E-06	A
Strontium-89	3E-01	3 0E-12	D	2 9E-12	4 7E-10	A
Strontium-90 +D	3E-01	3 6E-11	D	6.2E-11	0 0E+00	A
Tritium	1E+00	5 4E-14	*	7 8E-14	0 0E+00	A
Uranium-233,234[3]	5E-02	1 6E-11	Y	2 6E-08	3 0E-11	A
Uranium-235 +D	5E-02	1 6E-11	Y	2 5E-08	2 4E-07	A
Uranium-238 +D	5E-02	2 8E-11	Y	5 2E-08	3 6E-08	A

Source HEAST 1993

(1)=Gastrointestinal (GI) absorption factors are the fractional amounts of each radionuclide absorbed across the GI tract into the bloodstream

(2)=Lung clearance classification recommended by the International Commission on Radiological Protection (ICRP) y=year, w=week, d=day, *=gas

(3) = Slope factors shown are for U-234

A = Class A (human) carcinogen

+D = Risks from radioactive decay products included A25

TABLE 2-3
USEPA CARCINOGENICITY WEIGHT-OF-EVIDENCE CLASSIFICATIONS

Group A	Human Carcinogen (sufficient evidence of carcinogenicity in humans)
Group B	Probable human carcinogen
	B1 Limited evidence of carcinogenicity in humans B2 Sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)
Group C	Possible human carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data)
Group D	Not classifiable as a human carcinogen (inadequate or no evidence)
Group E	Evidence of noncarcinogen for humans (no evidence of carcinogen for humans (no evidence of carcinogenicity in adequate studies)

TABLE 2-4
ROCKY FLATS OU6
EFFECTIVE DOSE COEFFICIENTS FOR CHIEF RADIONUCLIDES OF CONCERN (1)

Radionuclide	f_i (2)	Ingestion (Sv/Bq)	Class (3)	Inhalation (Sv/Bq)	External (4)
Americium-241	1 00E-03	9 84E-07	W	1 20E-04	2 99E+00
Plutonium-239	1 00E-03	9 56E-07	W	1 16E-04	3 78E-02
	1 00E-04	9 96E-08	Y	8 33E-05	
	1 00E-05	1 40E-08			
Uranium-234	5 00E-02	7 66E-08	D	7 37E-07	8 07E-02
	2 00E-03	7 06E-09	W	2 13E-06	
			Y	3 58E-05	
Uranium-235	5 00E-02	7 19E-08	D	6 85E-07	1 71E+01
	2 00E-03	7.22E-09	W	1 97E-06	
			Y	3 32E-05	
Uranium-238	5 00E-02	6 88E-08	D	6 62E-07	6 46E-02
	2 00E-03	6 42E-09	W	1 90E-06	
			Y	3 20E-05	

(1) Identified as radionuclides of concern in the Chemical of Concern Technical Memorandum (USDOE 1994)

(2) Fractional uptake from small intestine to blood

(3) Lung clearance class D = days, W = weeks, Y = years

(4) In units of millirem/yr per microcurie/square meters